JACC Vol. 25, No. 7
June 1995:1740–3

LETTERS TO THE EDITOR

Computer-Simulated and Clinical Models Agree on Optimal Postoperative Management for Hypoplastic Left Heart Syndrome

The postoperative management of children after Stage I palliation of hypoplastic left heart syndrome is a daunting task. The recent report by Barnea et al. (1) is a major contribution toward a better understanding of this complex physiology. In contrast to most of the accepted management strategies based on experience (trial and error), the authors provide an elegant mathematical analysis of how systemic oxygen delivery can be optimized in the face of parallel circulations.

Earlier publications (2,3) have suggested that survival was improved when the arterial saturation was maintained in the range 75% to 80%, implying a pulmonary/systemic flow ratio (Q_p/Q_s) close to unity. Barnea et al. (1) showed that with little deviation in systemic arterial oxygen content from that "optimal range," there was a potential for marked variation in cardiac output, systemic oxygen delivery and Q_p/Q_s ratio. They also proved that maximal systemic oxygen delivery (the product of arterial oxygen content [Cao_2] and Q_s) occurred at a Q_p/Q_s ratio <1 for *all* values of cardiac output and pulmonary venous saturation. They suggested that clinical measurement of venous saturations would be useful, allowing one to calculate and optimize Q_p/Q_s.

Our recently published report (4) described exactly that method, after Stage I palliation for hypoplastic left heart syndrome in 13 patients. By assuming pulmonary venous saturation of 95%, and by measuring superior vena cava saturation intermittently (using a 3F indwelling catheter placed at operation), we were able to demonstrate marked abnormalities in Q_p/Q_s despite "optimal" systemic arterial saturations, exactly as predicted by the mathematical model of Barnea et al (1). We were then able to direct changes in the patient's ventilation, inotropic and vasodilator support to achieve a Q_p/Q_s as close to unity as possible. Using this strategy, our experience in Stage I patients has been very rewarding, with 27 of 32 Stage I patients (84%) ultimately discharged home from the hospital.

We disagreed with the last conclusion of Barnea et al. (1) that when both systemic arterial and systemic venous saturations are low, Q_p should be increased. With an acceptable systemic arteriovenous oxygen difference (<25%), Q_s should also be acceptable. To intervene to increase Q_p relative to Q_s would be to "steal" flow from the systemic circulation. That manipulation may result in a higher arterial saturation at the expense of lower systemic oxygen delivery. The curve on which the authors' recommendation is based (Fig. 5) assumes a pulmonary vein saturation of 96% (1). Obviously, with lower pulmonary venous saturation Q_p/Q_s and oxygen delivery are better than the model would predict. At the bedside, we would have given oxygen to rule out pulmonary venous desaturation because we also assumed normal pulmonary venous saturation.

With no response to oxygen, we would have attempted to improve both Q_p and Q_s by increasing inotropic or vasodilating agents, or both, before trying to selectively dilate the pulmonary circuit.

Although both computer-simulated and clinical studies oversimplify complex "whole-body" events, as Barnea et al. correctly point out in their conclusion (1), results of each indicate that monitoring venous saturations and optimizing Q_p/Q_s appear to be critical to outcome in patients with parallel circulations.

ROBERT J. SOMMER, MD
ANTHONY F. ROSSI, MD
RANDALL B. GRIEPP, MD
Division of Pediatric Cardiology and
Department of Cardiothoracic Surgery
Mount Sinai Medical Center
New York, New York 10029

References

1. Barnea O, Austin EH, Richman B, Santamore WP. Balancing the circulation: theoretic optimization of pulmonary/systemic flow ratio in hypoplastic left heart syndrome. J Am Coll Cardiol 1994;24:1376–81.
2. Meliones JN, Snider AR, Bove EL, Rosenthal A, Rosen DA. Longitudinal results after first stage palliation for hypoplastic left heart syndrome. Circulation 1990;82 Suppl IV:IV-151–6.
3. Lang P, Norwood WI. Hemodynamic assessment after palliative surgery for hypoplastic left heart syndrome. Circulation 1983;68:104–8.
4. Rossi AF, Sommer RJ, Lotvin A, et al. Usefulness of intermittent monitoring of mixed venous saturation after stage I palliation for hypoplastic left heart syndrome. Am J Cardiol 1994;73:1118–23.

Reply

Within days of acceptance of our theoretic analysis (1), we were pleased to see the publication by Rossi et al. (2) demonstrating the value of monitoring systemic mixed venous oxygen saturation after first-stage palliation of hypoplastic left heart syndrome. As our theoretic model predicted, they showed clinically that even with large variations in the pulmonary/systemic ratio (Q_p/Q_s), arterial oxygen saturation changes were minimal. In contrast, mixed venous oxygen saturations provided a sensitive monitor of changes in Q_p/Q_s. Although both publications directed attention to hypoplastic left heart syndrome, the importance of monitoring systemic mixed venous oxygen saturation should also be relevant to other univentricular circulations.

We were also pleased that Rossi et al. had critically reviewed our report and responded with the preceding letter. The sole point of disagreement centers around our recommendation that when both systemic arterial and systemic venous saturations are low, Q_p should be increased. Our statement was based on Figure 5 in our report and thus assumed that cardiac output and pulmonary venous oxygen saturation were constant. In our model, because oxygen availability appeared to peak at a Q_p/Q_s ratio of ~0.5, our recommendation referred to situations where the Q_p/Q_s ratio was less than this value. Although we recognize the concern that increasing Q_p relative to Q_s may "steal" flow from the systemic circulation, exact calculations with our model indicate that systemic oxygen availability would actually increase. As an example (from Fig. 2 in our study), with pulmonary venous oxygen saturation at 96% and cardiac output at 800 ml/min, increasing the Q_p/Q_s ratio from 0.25 to 0.50 increases pulmonary blood flow by 67% but only decreases systemic blood flow by 17%. The net effect is an increase in systemic oxygen availability from 63.2 to 76.6 ml/O_2 per min.

It is, of course, unrealistic to expect that cardiac output and pulmonary venous oxygen saturation will remain constant in a clinical situation. Thus, possible changes in either or both of these variables must be considered in interpreting systemic arterial and mixed venous

0735-1097/95/$9.50
0735-1097(95)00034-2

saturations. Our model also indicates that if the Q_p/Q_s ratio is kept constant, oxygen availability is improved by increasing pulmonary venous saturation or cardiac output. Thus, we must acknowledge and appreciate the point that in a clinical setting, pulmonary venous desaturation must be ruled out and adequate cardiac output ensured.

We thank Rossi et al. for their thoughtful comments and compliment them on a fine clinical study.

ERLE H. AUSTIN III, MD, FACC
Division of Surgery and Cardiovascular Surgery
School of Medicine
University of Louisville
Louisville, Kentucky 40292

References

1. Barnea O, Austin EH, Richman B, Santamore WP. Balancing the circulation: theoretic optimization of pulmonary/systemic flow ratio in hypoplastic left heart syndrome. J Am Coll Cardiol 1994;24:1376–81.
2. Rossi AF, Sommer RJ, Lotvin A, et al. Usefulness of intermittent monitoring of mixed venous saturation after stage I palliation for hypoplastic left heart syndrome. Am J Cardiol 1994;73:1118–23.

Blood Pressure Measurement in Athletes

At the 26th Bethesda Conference (1), a panel of experts made timely recommendations for determining eligibility for competition in athletes with cardiovascular abnormalities. However, we would like to point out an incorrect recommendation made by Task Force 4 (2) with regard to selection of the correct blood pressure cuff. This recommendation is a reflection of the deeply rooted confusion created by various committees and task forces over the years.

Probably the two most important considerations for the diagnosis of systemic hypertension are the correct blood pressure measuring technique, especially selection of the correct size of blood pressure cuff, and the availability of normal blood pressure levels developed by the same technique. Task Force 4 (2) recommends that the blood pressure cuff cover two thirds of the length of the arm and presented the classification of hypertension for children and adolescents on the basis of the recommendations of the Second (1987) National Institutes of Health (NIH) Task Force on Blood Pressure Control in Children (3). The normative data in the second NIH Task Force report were obtained by the use of a blood pressure cuff three quarters, rather than two thirds, of the length of the arm.

The size of the blood pressure cuff should be chosen by the thickness, not the length, of the arm (4,5) based on the transmission of cuff pressure to the artery. In the adult, the width of the blood pressure cuff is selected by the thickness of the arm, 40% to 50% of the circumference of the arm (or 125% to 155% of the diameter of the arm) (5). For reasons that are not stated, but lacking physical ground, the First NIH Task Force in 1977 recommended the use of a blood pressure cuff to cover two thirds of the length of the upper arm and provided normative blood pressure data (6) based on that cuff size. In 1987, the Second NIH Task Force changed its recommendation to three quarters of the length of the arm without any explanation or supporting data (5), with a new set of normative data that are much lower than the 1977 normative data.

A Special Task Force of the American Heart Association (AHA) in 1988 recommended that the blood pressure cuff be selected by the same criterion as that in the adult (5), confirming our earlier recommendations (7). This recommendation is based on several reports that demonstrated a close approximation of auscultatory blood pressure with direct arterial pressures and provides consistency and continuity in the methodology of blood pressure measurement in children and adults (see Ref. 4 for review).

Table 1. Suggested Normal Blood Pressure Levels by Auscultatory Method (systolic/diastolic K5)

Age (yr)	Mean BP Levels (mm Hg)	90th Percentile (mm Hg)	95th Percentile (mm Hg)
6–7	104/55	114/73	117/78
8–9	106/58	118/76	120/82
10–11	108/60	120/77	124/82
12–13	112/62	124/78	128/83
14–15			
Boys	116/66	132/80	138/86
Girls	112/68	126/80	130/83
16–18			
Boys	121/70	136/82	140/86
Girls	110/68	125/81	127/84

Blood pressure (BP) values are adapted from Goldring et al. (8) and Prineas et al. (9), with the blood pressure cuff width selected to be 40% of the circumference of the upper arm. Values for ages 10 to 13 years have been extrapolated from these two studies using age-related increments from other studies.

The blood pressure cuff selected to be two thirds of the length of the arm may produce blood pressure readings that are close to normal for subjects of average weight for height, but this cuff would create iatrogenic hypertension if used in obese subjects or in athletes whose arm girth may be larger than average. We believe that the recommendations of the 1988 AHA committee should be adopted, namely, that the blood pressure cuff is selected to be 40% to 50% of the circumference (or 125% to 155% of the diameter) of the arm, especially for checking blood pressure in athletes. Many physiologic differences exist between children and adults, but certain physical principles, such as that of blood pressure measurement, are not age dependent.

Finally, the AHA recommendations were unfortunately not accompanied by normative data. Until normative data using the AHA cuff selection criterion become available, the normative BP values shown in Table 1 could be used (4). These data are derived from two large epidemiologic studies (8,9) in which the blood pressure cuff was selected by the thickness of the arm. Normative blood pressure levels for children 10 to 13 years were extrapolated by age-related increments. Normative blood pressure levels for children and adolescents (kindergarten through the 12th grade) using the AHA recommendations are being developed at this time.

MYUNG K. PARK, MD, FACC
Department of Pediatrics
University of Texas Health Science Center
San Antonio, Texas 78184-7804

WARREN G. GUNTHEROTH, MD, FACC
Department of Pediatrics
University of Washington School of Medicine
Seattle, Washington 98195

References

1. Maron BJ, Mitchell JH. 26th Bethesda Conference: recommendations for determining eligibility for competition in athletes with cardiovascular abnormalities. J Am Coll Cardiol 1994;24:845–99.